

## CLAIMS

1. A method of attaching a self-piercing element in a panel supported on a die member, said self-piercing element including a tubular barrel portion having an open free end including a piercing surface and an integral radial flange portion
- 5 adjacent said tubular barrel portion including an outer surface having a plurality of spaced inwardly concaved surfaces, said die member including a panel supporting end face, a central die post having an end surface including a piercing surface spaced below the plane of said end face and an annular die cavity surrounding said central die post, said annular die cavity including a semicircular annular bottom surface and a
- 10 side wall extending from said semicircular annular bottom surface to said end face, said method comprising the following steps:
- supporting a panel on said end face of said die member;
- driving said open free end of said self-piercing element against said panel and said panel against said end surface of said die post;
- 15 continuing to drive said open free end of said barrel portion against said panel, piercing a slug from said panel between said piercing surfaces of said barrel portion and said end surface of said central die post, forming an opening through said panel, and simultaneously deforming a first portion of said panel adjacent said opening into said annular die cavity against an outer surface of said
- 20 tubular barrel portion;
- driving said open free end of said barrel portion against said semicircular annular bottom surface of said annular die cavity, deforming said free open end of said barrel portion radially outwardly and upwardly toward said end face, forming a U-shaped end portion of said barrel portion, and deforming a pierced edge
- 25 of said panel portion into said U-shaped end portion of said barrel portion; and

continuously, incrementally deforming a second panel portion in said annular die cavity between said outer surface of said flange portion of said self-piercing element and said side wall of said annular die cavity radially into said inwardly concave surfaces.

5           2.       The method as defined in Claim 1, wherein said side wall is a continuous frustoconical side wall extending tangentially from said bottom surface having an included angle of between 5 degrees and 12 degrees, and said method includes deforming said free open end of said barrel portion upwardly adjacent to but spaced from said side wall.

10           3.       The method as defined in Claim 1, wherein a distance between said continuous frustoconical side wall adjacent said end face and said outer surface of said flange portion is less than the thickness of said panel, said method including thinning said panel at locations between said spaced inwardly concave surfaces.

             4.       The method as defined in Claim 1, wherein said method includes  
15 maintaining said first panel portion spaced from said outer wall of said annular die cavity.

             5.       A method of attaching a self-piercing element in a panel supported on a die member, said self-piercing element including a tubular barrel portion having an open free end and an integral radial flange portion adjacent said tubular barrel portion  
20 having a generally cylindrical outer surface including a plurality of spaced inwardly concave surfaces, said die member including an end face, a central die post having an end surface spaced below the plane of said end face and an annular die cavity surrounding said central die post, said annular die cavity including an annular semicircular bottom surface and a frustoconical side wall extending tangentially from  
25 said semicircular bottom surface to said end face, said method comprising:

supporting a panel on said end face of said die member;

driving said open free end of said barrel portion of said self-piercing element against said panel and said panel against said end surface of said central die post;

5 continuing to drive said open free end of said barrel portion against said panel, thereby piercing a slug from said panel between said open free end of said barrel portion and said end surface of said central die post;

continuing to drive said open free end of said self-piercing element against said panel, thereby piercing a slug from said panel between said open free end  
10 of said barrel portion and said end surface of said central die post, forming an opening through said panel, and simultaneously deforming an end portion of said panel adjacent said opening into said annular die cavity against an external surface of said tubular barrel portion around an intersection of said end face and said continuous smooth frustoconical annular side wall of said die member;

15 driving said free open end of said barrel portion against said semicircular annular bottom surface of said annular die cavity, thereby deforming said free open end of said barrel portion radially outwardly and upwardly toward said end face and around said end portion of said panel, thereby forming a U-shaped end portion of said barrel portion enclosing said end portion of said panel; and

20 continuously, incrementally deforming a second panel portion in said annular die cavity adjacent said end face of said die member between said cylindrical surface of said flange portion and said side wall, thereby thinning said second panel portion and deforming said second panel portion radially into said plurality of spaced inwardly concave surfaces while the remainder of said panel is spaced from side wall.

6. The method of Claim 5, wherein said method includes deforming said pierced edge of said first panel portion in said U-shaped end portion into an enlarged bead having a thickness greater than the thickness of said panel and having a height measured between said flange portion and said U-shaped end portion of said barrel portion greater than its width.

7. A die member for attaching a self-piercing element including a tubular barrel portion and a radial flange portion in a panel, said die member comprising:  
an end face, a central die post extending generally perpendicular to said end face having an end surface, and an annular die cavity surrounding said central die post, said annular die cavity including an annular semicircular bottom surface and a continuous smooth frustoconical side wall extending tangentially from said semicircular bottom surface to said end face.

8. The die member as defined in Claim 7, wherein said continuous smooth frustoconical side wall has an included angle of between 5 and 12 degrees.

9. The die member as defined in Claim 7, wherein said continuous frustoconical side wall joins said end face in a radiused surface having a radius of less than 0.04 inches.

10. The die member as defined in Claim 7, wherein said central die post has an outer piercing edge defined by an outer annular planar end surface and a frustoconical side wall extending tangentially from said semicircular bottom surface to said outer annular planar surface at an included angle of about 7 degrees.

11. A die member for attaching a self-piercing element having a tubular barrel portion and a radial flange portion in a panel supported on said die member, said die member comprising:

a generally planar panel-supporting end face, an annular concave die cavity defined in said end face, and a central die post projecting from said annular concave die cavity toward said end face including an end surface spaced below the plane of said generally planar panel-supporting end face and an outer piercing surface, 5 said annular concave die cavity including an annular semicircular bottom surface and a continuous smooth frustoconical outer side wall extending tangentially from said annular semicircular bottom surface to said end face having an included angle of between 5 and 12 degrees.

12. The die member as defined in Claim 11, wherein said frustoconical 10 outer side wall joins said end face in a radiused surface having a radius of less than 0.04 inches.

13. The die member as defined in Claim 11, wherein said outer piercing surface of said central die post is defined by an outer annular planar surface and a frustoconical inner surface extending tangentially from said annular semicircular 15 bottom surface to said outer annular planar surface defining a sharp piercing edge.

14. A self-piercing male fastener element comprising a shank portion, a radial flange portion integral with said shank portion and a tubular barrel portion integral with said radial portion including a free open end portion having a piercing surface for piercing an opening in a panel, said flange portion including a generally 20 planar annular bearing surface surrounding said shank portion having a diameter greater than said barrel portion and an outer surface having a plurality of spaced concave surfaces, wherein the area of said annular bearing surface is at least five times the area of said concave surfaces measured in the plane of said generally planar bearing surface.

15. The self-piercing male fastener element as defined in Claim 14, wherein said area of said bearing surface is at least six times said area of said concave surfaces measured in the plan of said bearing area.

16. The self-piercing male fastener element as defined in Claim 14,  
5 wherein said concave surfaces are spaced from said tubular barrel portion a distance equal to or greater than the depth of said concave surfaces.

17. The self-piercing male fastener element as defined in Claim 14, wherein the depth of said concave surfaces about 0.75 the width of said bearing surface measured from said shank portion.